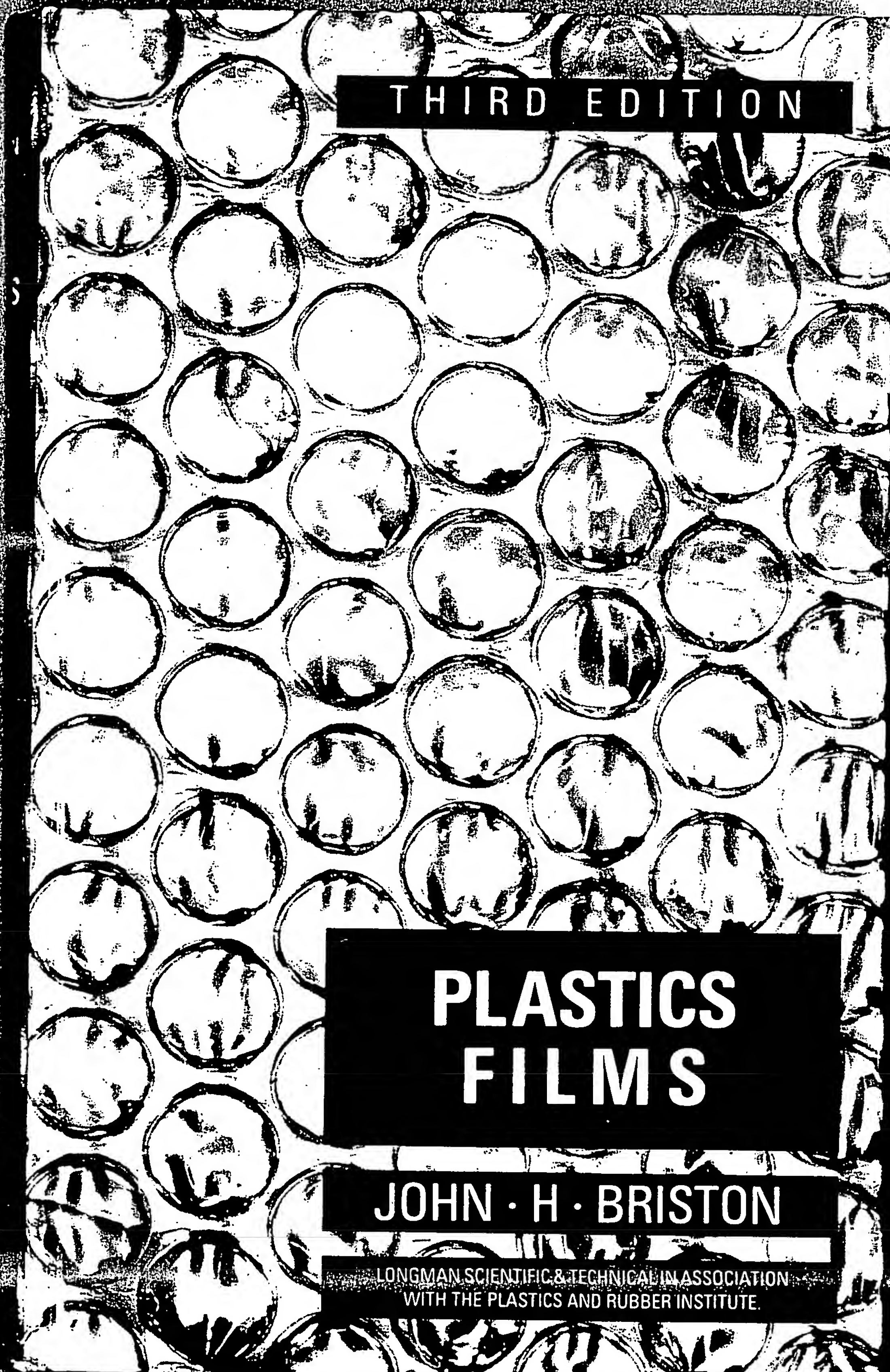
THIRD EDITION
PLASTICS
FILMS
JOHN · H · BRISTON
LONGMAN SCIENTIFIC & TECHNICAL IN ASSOCIATION
WITH THE PLASTICS AND RUBBER INSTITUTE.

PLASTICS FILMS

JOHN · H · BRISTON

The many applications for plastics films has grown rapidly over recent years, especially in the field of packaging. This book has long been the established work on this subject because of its unified approach which includes not only film forming materials and their properties but also the important topics of film manufacture, film conversion (printing, lamination, wrapping and bag manufacture) and end-uses such as packaging applications, agriculture, horticulture, building and construction, synthetic papers, film tapes and fibres.

For this third edition the opportunity has been taken to extensively update and revise the text to take account of recent advances in materials conversion processes. In particular, the section on vacuum and gas packaging has been expanded to cover controlled/modified atmosphere packaging, while the chapter on thermoforming has been rewritten to incorporate sections on control of wall thickness, automatic operation and solid phase pressure forming. A new appendix covering additives for plastics films has been included and the chapters on organolepsis and health safety have also been completely re-written by Dr L L katan, reflecting their continuing importance, especially to the food industry.

All technologists in the fields of packaging and plastics, whether as covertors or users of films and laminates or film manufacturers in the pharmaceutical, food, agricultural printing, cosmetics or toiletries industries, will welcome this new edition of a valuable handbook. Students of polymer science and those studying for the membership examinations of the Plastics and Rubber Institute or the Institute of Packaging will find it a useful reference text.

John Briston, BSc., CChem., FRSC, FPRI, FInstPkg., is a consultant specialising in the use of plastics for the packaging industry. He is a past National Chairman of the Institute of Packaging and past Chairman of the Plastics and Rubber Insitute's Packaging Group. He is the author of several books on packaging and plastics technology and has contributed over 150 technical papers to leading journals in these fields. He has also lectured widely in the UK and overseas.

Leonard Katan, BSC., PhD., FIChemE., DIC., ARCS, CEng., FPRI, was previously head of the Polymer Safety and Environmental Department at the Shell Group. He is currently a consultant in health safety and environmental matters related to food packaging. He is also editor of FCD (Food, Cosmetics and Drugs) Packaging Bulletin and has published over thirty papers and five books in this field.

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Plastics Films

Third edition

J. H. Briston, B.Sc., C.Chem., F.R.S.C., F.P.R.I., F.Inst.Pkg.

With two chapters by

Dr L. L. Katan, B.Sc., Ph.D., F.I.Chem.E., D.I.C., A.R.C.S., C.Eng., F.P.R.I.

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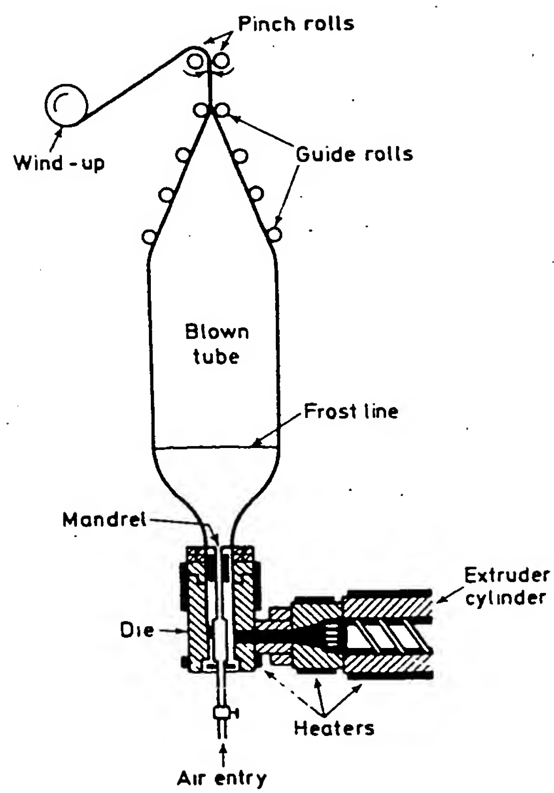

Figure 8.2. Blown film extrusion

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iso sometimes used, particularly for
uce porosity, when the screw must be
g in order to prevent rearward polymer

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vn advantages and limitations. In general,
ıre more expensive and because of their
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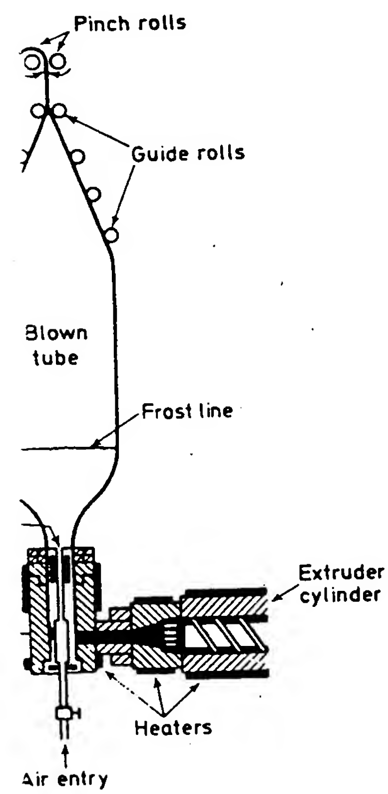

sion

8.1.1 BLOWN FILM EXTRUSION

A typical set-up for blown film extrusion is shown in *Figure 8.2.* In this instance the molten polymer from the extruder enters the die from the side but entry can also be effected from the bottom of the die. Once in the die, the molten polymer is made to flow round a mandrel and emerges through a ring shaped die opening, in the form of a tube. The tube is expanded into a bubble of the required diameter by an air pressure maintained through the centre of the mandrel. The expansion of the bubble is accompanied by a corresponding reduction in thickness. Extrusion of the tube is usually upwards but it can be extruded downwards, or even sideways. The bubble pressure is maintained by pinch rolls at one end and by the die at the other. It is important that the pressure of the air is kept constant in order to ensure uniform thickness and width of film. Other factors that affect film thickness are extruder output, haul-off speed and temperatures of the die and along the barrel. These must also be strictly controlled.

As with any extrusion process, film blowing becomes more economical as speeds are increased. The limiting factor here is the rate at which the tubular extrudate can be cooled. Cooling is usually achieved by blowing air against the outside surface of the bubble. Under constant air flow conditions an increase in extrusion speed results in a higher 'frost' line (the line where solidification of the extrudate commences) and this leads to bubble instability. Increasing the air flow gives more rapid cooling and lowers the 'frost' line but this is limited in its application because too high a velocity of the air stream will distort the bubble. Various designs of air cooling rings have been worked out in order to produce improved cooling without these attendant difficulties and one such design (designed and patented by Shell) is shown in *Figure 8.3*. It consists of a conically shaped ring provided with three air slits, the airstreams from which are so directed and regulated that the space between the bubble and the ring decreases gradually towards the top of the ring. This gives improved cooling by increasing the speed of the airstream. The design also results in a zone of under-pressure at the top of the ring and this greatly improves the bubble stability.

Blown film extrusion is an extremely complex subject and there are many problems associated with the production of good quality film. Among the many defects which can occur are variations in film thickness, surface defects such as 'orange peel', 'apple sauce' or 'fish eyes', low tensile strength, low impact strength, hazy film, blocking and wrinkling. Wrinkling is a particularly annoying problem because it can be costly, leading to scrapping of a roll of

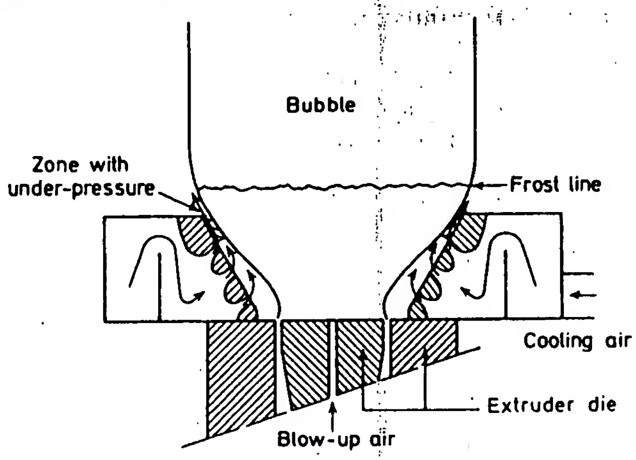

Figure 8.3. Shell cooling ring

film, and because it can arise from such a wide variety of causes that it is likely to occur even in the best regulated extrusion shop. If the film is too cold when it reaches the pinch rolls, for instance, it will be stiff and this may cause crimping at the nip and wrinkling. One way of raising the film temperature at the nip rolls is to raise the melt temperature but this can lead to other troubles such as blocking. In fact, this is illustrative of the whole subject of film blowing inasmuch as compromises are often necessary to achieve the best balance of properties. Wrinkling can also be caused by the die gap being out of adjustment. This causes variations in film thickness and can lead to uneven pull at the pinch rolls. Another cause of wrinkling may be surging from the extruder or air currents in the extruder shop. Both of these factors can cause wobbling of the film bubble and thus wrinkling at the wind-up stage. The film bubble may be stabilised by supporting it with horizontal stationary guides or the whole extruder may be protected from stray air currents by a film curtain. Other causes include non-alignment of the guide roll and the pinch rolls, or non-uniformity of pressure across the face of the pinch rolls.

Among the surface defects mentioned earlier, 'fish eyes' are due to imperfect mixing in the extruder or to contamination. Both of these factors are controlled by the screen pack which not only screens out contaminating particles but improves homogeneity by increasing the back pressure in the extruder. 'Orange peel' or

'apple sauce' are also surface defects caused by inhomogeneity of the molten polymer.

Since low density polyethylene forms by far the greatest percentage of all film made, it will be useful to consider the influence of the various polymer parameters such as melt flow index and molecular weight on the film properties. Impact strength, for instance, increases with molecular weight (i.e. with decreasing melt index) and with decreasing density. Heavy duty sacks, for instance, are normally made from polyethylene grades having densities between 0.916 and 0.922 g/cm^3 and melt indices between 0.2 and 0.5. For thinner technical film as used in building applications or waterproof lining of ponds, higher melt indices have to be used because of the difficulty of drawing down very viscous melts to thin film. Melt indices of between 1 and 2.5 are more usual, therefore, and impact strengths are less than for heavy duty sacks. Clarity is, however, improved. Where a good balance of properties is required as in the medium clarity/medium impact grades, slightly higher densities are used (0.920 to 0.925 g/cm^3) and the melt index is varied between 0.75 and 2.5. For high clarity, a high density and a high melt index are required since increases in both these properties cause an increase in see-through clarity, a decrease in haze and an increase in gloss. High clarity film will, of course, have a relatively poor impact strength because of the high melt index and such film should not be used for packaging heavy items.

8.1.2 SLIT-DIE EXTRUSION (FLAT FILM EXTRUSION)

In flat film extrusion the molten polymer is extruded through a slit-die and thence into a quenching water bath or on to a chilled roller. In either case the essence of the process is rapid cooling of the extruded film and cooling is, therefore, applied within a very short distance of the die lips (usually between 25 and 65 mm—1.0 in and 2.6 in). This short distance is also dictated by the necessity to reduce 'necking' of the film web, with consequent loss of width. In the chill roll casting method, the melt is extruded onto a chromium plated roller, cored for water cooling *(Figure 8.4)*. The rapid cooling leads to the formation of small crystallites and this gives a clearer film.

Where the quench bath method is used, the water temperature should be kept constant for best results. At constant extrusion temperature, lower quench temperatures improve slip and anti-blocking properties while higher quench temperatures give film that is easier to wind without wrinkles and with better physical properties.

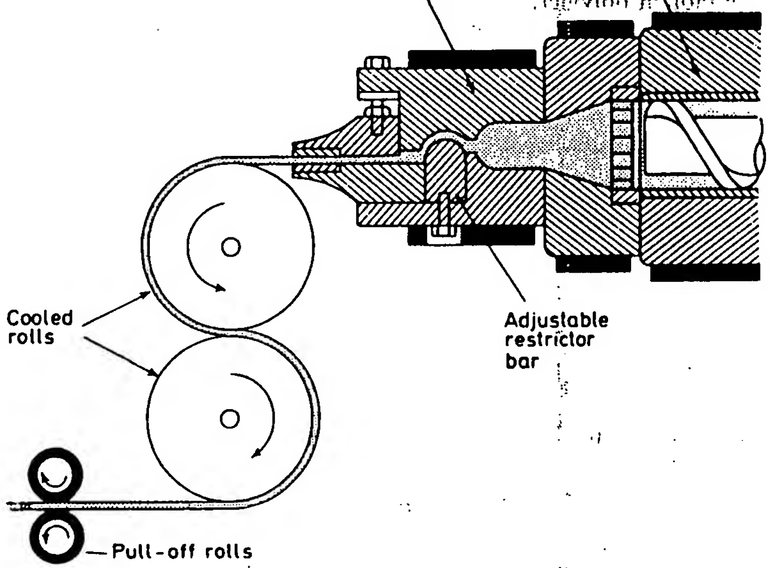

Figure 8.4. Film casting (slit-die extrusion)

Slit-dies for flat film are wide in comparison with the diameter of the extruder head and this means that the flow path to the extreme edges of the die is longer than to the centre. Flow compensation

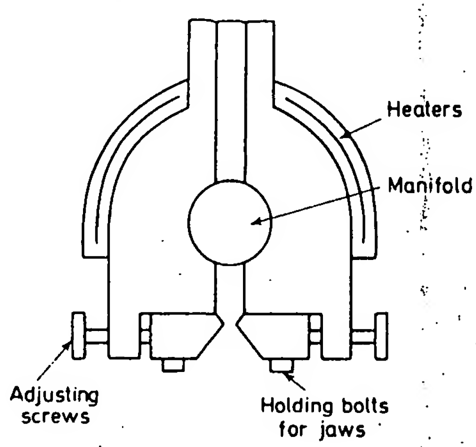

Figure 8.5. Cross-section of manifold-type die for film

is usually obtained by a manifold die, a cross-section of which is shown in *Figure 8.5*. It consists of a lateral channel (or manifold) of such a diameter that the flow resistance is small compared with that offered by the die lips. The manifold can only be efficient in its task of flow compensation if the viscosity of the melt is fairly low so that higher temperatures are necessary for flat film extrusion. This limits the use of the manifold die to materials of good thermal stability while another consequence of the higher extrusion temperature is the necessity for a heavier screen pack in order to maintain satisfactory back pressures. The inside surface of a flat die has to be precision machined and well polished since the slightest surface imperfection will result in striations or variations in gauge.

8.1.3 COMPARISON OF BLOW AND CAST FILM PROCESSES

Some of the advantages of the tubular film process are as follows:

(1) The mechanical properties of the film are generally better than those of cast film.
(2) The width of lay flat film is easily adjustable and there are no losses due to edge trimming. This latter is necessary for flat film because of the thickening of the film edge due to necking-in.
(3) Lay flat film is more easily converted into bags since it is only necessary to seal one end of a cut length to make the bag.
(4) The cost for making wide blown film is much lower than for wide cast film because the cost of chill rollers increases rapidly with width due to the difficulty of precision grinding longer rollers.
(5) A tubular film die is more compact and is cheaper than a slit-die producing film of comparable width.
(6) The tubular process is easier and more flexible to operate.

These advantages must be balanced against the advantages of the slit-die process which are as follows:

(1) Very high outputs can be obtained by slit-die extrusion units.
(2) Slit-die film normally has superior optical properties but it should be noted that special rapid cooling processes have been developed for tubular film, particularly in the case of

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